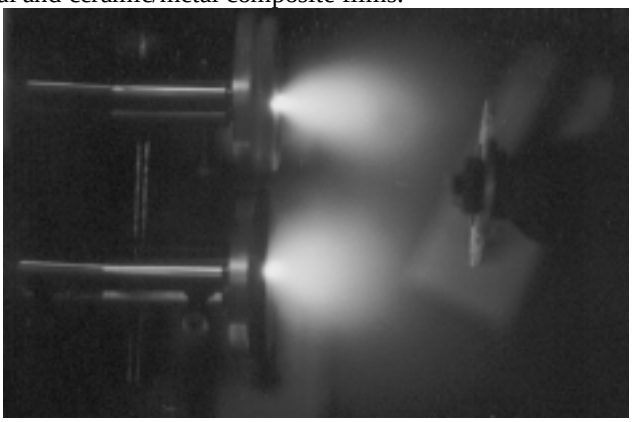
Combinatorial Tools for Dielectric Oxide Thin Films

Peter K. Schenck, Debra L. Kaiser

Dielectric oxide films are leading candidate materials for next generation wireless, memory and logic devices. Combinatorial methods are ideally suited for the selection of materials for these applications. Industrial participants at the NIST/ARO sponsored Workshop "Combinatorial Materials Science: A National Dialogue" cited a need for measurement tools and databases of information on advanced materials. We are developing novel approaches for library fabrication and high throughput property measurements with the goal of providing a database of processing/property diagrams.

We are engaged in a multi-laboratory project to develop combinatorial tools for the fabrication and characterization of dielectric oxide thin films for wireless communications. These tools will be applied to promising materials for these applications and a database of processing-composition-processing information will be generated.

We have designed and fabricated a novel, dual-beam, dual-target pulsed laser deposition (PLD) system for library film preparation. In the PLD process, the laser beam is split and focused onto two targets of differing composition. The plumes emanating from the two targets (shown below) interact, and a film of continuously variable composition deposits on the substrate. Modifications are planned to introduce additional processing variables (*i.e.*, temperature, laser fluence) into the PLD experiments. *In situ* imaging and spectroscopic characterization tools in the system will permit real-time control and optimization of the deposition process. The technique is broadly applicable to undoped and doped ceramic, metal and ceramic/metal composite films.

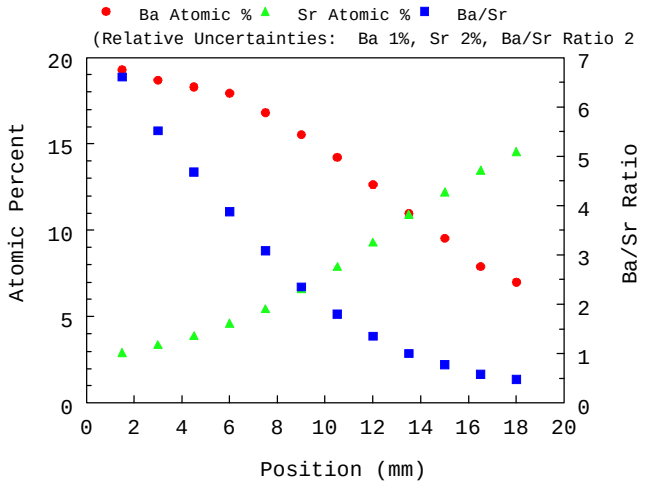


Photograph of plumes from $BaTiO_3$ (yellow) and $SrTiO_3$ (blue) targets in dual-beam PLD system.

The first system selected for study was $BaTiO_3$-$SrTiO_3$, a material that is presently being investigated for voltage tunable wireless devices. Library films have been deposited on 50.8 cm diameter (100)Si wafers at 25 °C and nominal 10 mm square Si substrates at 600 °C using $BaTiO_3$ and $SrTiO_3$ ceramic targets.

Thickness values, which are required for accurate measurement of the dielectric properties, were mapped by a semi-automated reflectance mode spectrophotometry technique at a spatial resolution of better than 1 mm.

The dielectric properties of (Ba,Sr)TiO_3 are strongly dependent upon the Ba/Sr ratio. Concentrations of Ba, Sr and Ti in a library film were measured by electron microprobe analysis using wavelength dispersive x-ray spectrometry (in CSTL). The Ba/Sr ratio, shown in the figure below, varied from 6.5 to 0.5 across the film.



Composition profile of a $BaTiO_3$-$SrTiO_3$ library.

Our collaborators in CSTL are developing a scanning evanescent microwave microscopy technique for mapping dielectric properties at high frequencies (up to 20 GHz). Efforts have focused on maximizing the sensitivity and frequency agility of the instrument. Measurements on one of the graded composition $BaTiO_3$-$SrTiO_3$ film libraries are currently underway.

Combined results on processing conditions, composition and dielectric properties will be stored in a database. Activities are ongoing in ITL to develop informatic protocols and methodologies for handling potentially large amounts of data from this project.

Contributors and Collaborators

Stephan J. Stranick, Steven W. Robey, Ryna B. Marinenko, John T. Armstrong, Chemical Science and Technology Laboratory (CSTL)
Barbara am Ende, Howard K. Hung , Judith E. Devaney, Information Technology Laboratory (ITL)